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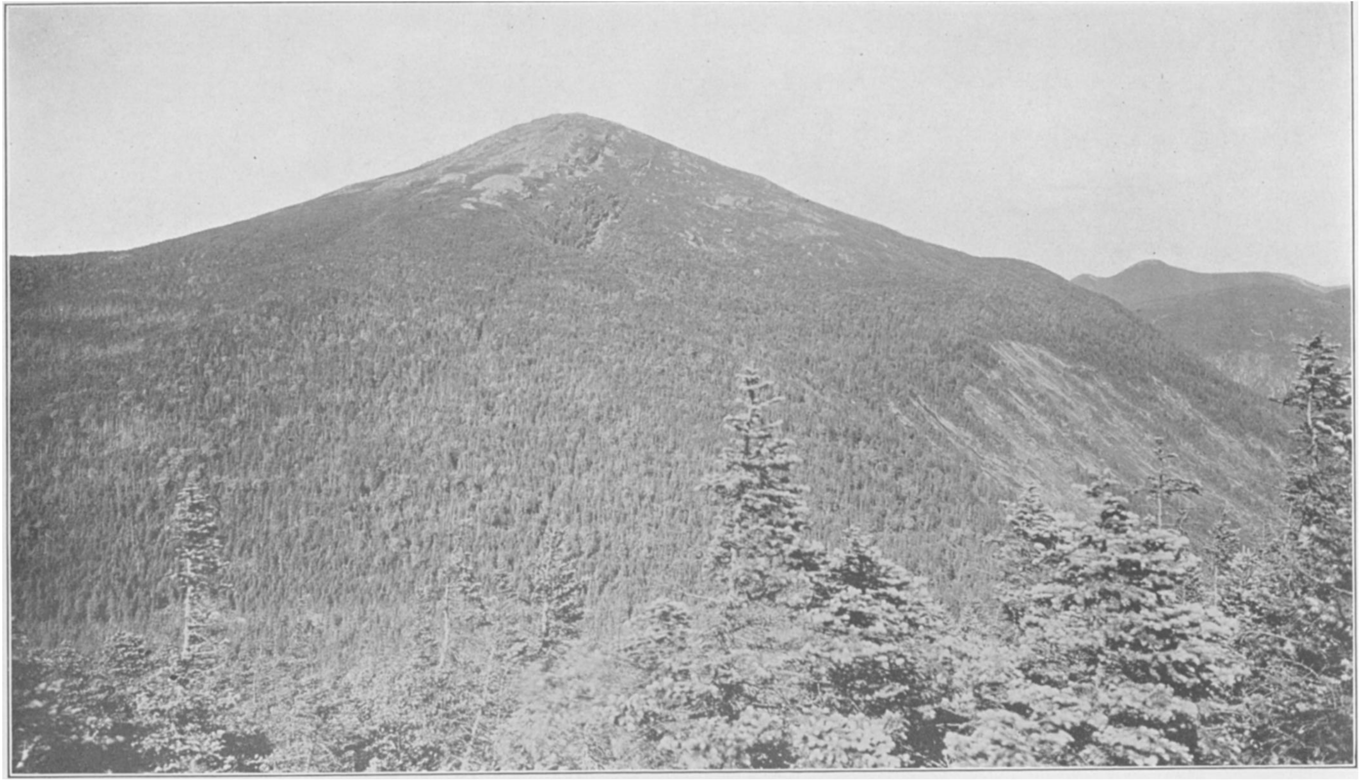

Frontispiece

By courtesy of the New York State Conservation Commission

Mount Marcy looking north from Mt. Skylight.

ECOLOGY

VOL. I APRIL, 1920 NO. 2

PLANTS AND ANIMALS OF MOUNT MARCY, NEW YORK, PART I.

CHARLES C. ADAMS, GEORGE P. BURNS, T. L. HANKINSON, BARRINGTON MOORE, AND NORMAN TAYLOR[1]

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I. THE PROBLEM

The purpose of the present investigation was to bring to bear upon the problem of timber line on mountains the methods of study and knowledge of botanists, zoologists, and foresters in order to learn more of the relation of plants and animals to their environment. Timber line gives a comparatively sharp line of demarkation between different habitats, which can here be readily contrasted; also the factors of the environment causing this differentiation of habitats can be studied to advantage along the line where their influence is so marked.[2] The severity of the conditions to which organisms are subjected above timber line gives a splendid opportunity for studying the effects produced by the environment upon the plants and animals which have been able to withstand these conditions.[3] Furthermore it is necessary to consider organisms in relation to their past history, and the zone above timber line is a promising place for investigations on post-glacial migration.[4] Hence timber line on Mt. Marcy in the Adirondack Mountains of New York was chosen as a favorable locality for this cooperative study. The elevation of Mt. Marcy is 5,344 feet, the highest of any point in New York State.

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[1] Members of the Committee on Cooperation of the Ecological Society of America, chairman Barrington Moore. The institutions cooperating and authors representing them were: the Brooklyn Botanic Garden (Taylor), Roosevelt Wild Life Forest Experiment Station of the New York State College of Forestry at Syracuse (Adams and Hankinson), Vermont Agricultural Experiment Station (Burns). Valuable assistance in the field arrangements, with the Ausable Club as a base, was rendered by Mr. Alfred T. White, chairman of the Governing Committee of the Brooklyn Botanic Garden.

Observation and correlation were largely used in this investigation; instrumental records over a brief period were also secured for air temperature, soil temperature, evaporation, and solar radiation. These records, though insufficient for absolute comparisons, yet have a distinct relative value in showing differences between critical points in the vegetative covering of the mountain.

DEFINITION OF TIMBER LINE USED IN THIS STUDY.—There is no *absolute tree line* on Mount Marcy, since stunted trees grow in patches practically up to the summit. But there is what may be called a *timber line,* that is a line at which the forest cover stops, giving place to open vegetation with clumps of stunted trees in the depressions. *For the purpose of this study the timber line is considered as the beginning of alpine vegetation except in ravines and other depressions. Characteristic alpine plants of Mt. Marcy are Empetrum nigrum, Rhododendron lapponicum, Diapensia lapponica, Solidago Cutleri, and Vaccinium caespitsum.* The timber line as above defined occurs at between 4,800 and 4,900 feet, mostly near 4,900 feet, and, where not interfered with by ravines and slides, extends around the mountain with remarkable regularity. There is no sharp distinction between north-facing and south-facing slopes as in the mountains of the West, the absence of this contrast in the Adirondacks probably being due to the abundant rainfall which masks the differences in insolation.[5] Ravines extend up the mountain carrying the forest in a continuous body above the timber line. These ravines are sometimes so wide as to create the impression that solid timber extends above 4,900 feet. Yet even here a difference seems to occur at an elevation of between 4,800 and 4,900 feet, for at about 4,890 feet the trees become considerably shorter and more stunted. Looking from above at one of these ravines, the change in the character of the trees at timber line can be clearly seen.

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[2] Much has been written on the environment above timber line. For a brief discussion see C. H. Shaw's "Vegetation and altitude," Plant World, Vol. 12, No. 3, pp. 63–64, 1909, and "Causes of timber line on Mountains," Plant World, Vol. 12, No. 8, pp. 169–181, 1909.

[3] See paper on "Anatomical reduction in some Alpine plants," by C. C. Forsaith, in this issue for an interesting piece of work on this subject.

[4] Adams, Charles C. "Postglacial origin and migrations of life of Northeastern United States," Jour. Geography, Vol. 1, No. 7, pp. 303–310, 1902.

————. "The postglacial dispersal of North American Biota," Biol. Bull., Vol. 9, pp. 53–71, 1905.

————. "Migration as a factor in evolution: its ecological dynamics," Am. Nat., Vol. 52, Oct.–Nov., 1918, and 53, Jan.–Feb., 1919.

Scharff, R. F. "Distribution and origin of life in America," MacMillan, New York, 1912.

II. THE REGION

MOUNT MARCY.—Mount Marcy lies in the eastern Adirondacks about 25 miles west of Lake Champlain. The mountain in profile is a low cone, with the upper few hundred feet forming a low dome. A general view of the south slope of the mountain, from Mount Skylight, is shown in the frontispiece, and a view of the upper part of the north slope, mainly above timber line, is shown in figure 1. The eastern and southeastern sides are more precipitous.

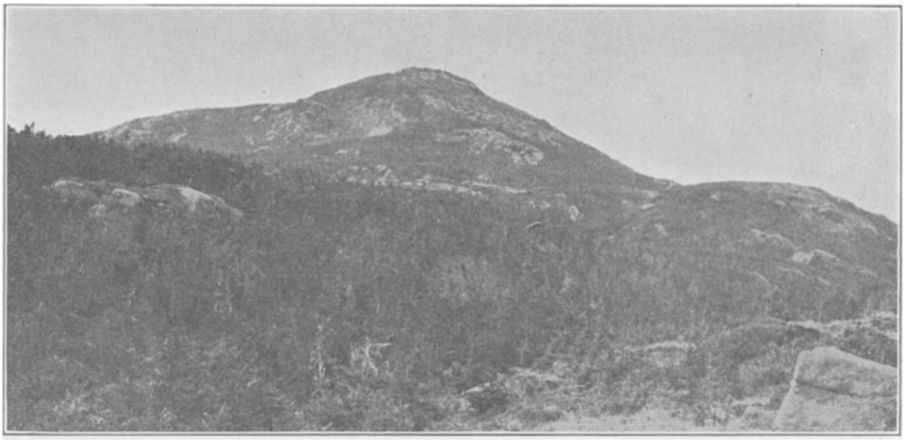

FIG. 1. North slope of Mt. Marcy from 4,850 feet elevation. Just below the summit on the left is the cirque containing a snowdrift; photographed June 5, 1919.

The conspicuous topographic features of the mountain above timber line are, ecologically considered, its isolation, its relatively small area and its relatively uniform relief. The isolation gives exposure on all sides. The domed surface favors rapid drainage, and the elevation into the cloud zone favors precipitation. There is a sphagnum bog on the northeast slope at about 5,000 feet, and a well-defined cirque (fig. 1) on the same slope at an elevation of 5,250 feet, later described and illustrated as the "Dwarf birch meadow." On the southwestern slope is a large ravine, which reaches to near the top of the mountain. The southeastern and eastern slopes are more

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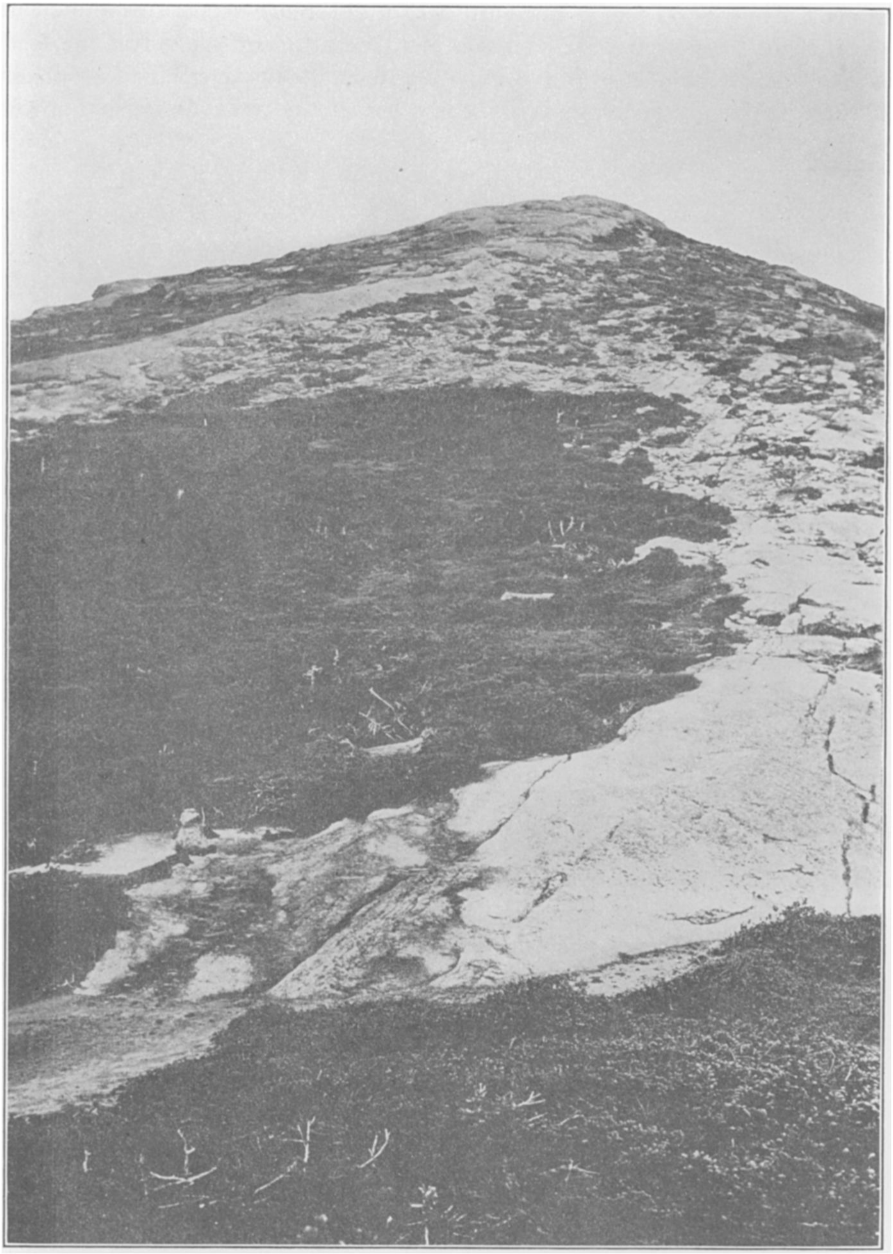
[5] Measurements of the rate of drying of the forest floor on north and south slopes are given by S. B. Show in his "Climate and forest fires in northern California," Journal of Forestry, Vol. 17, No. 8, pp. 965–979, 1919. Even greater contrasts are found in the Southern Sierras and in Arizona and New Mexico.



By courtesy of the New York State Conservation Commission.

FIG. 2. Southern trail slope of Mt. Marcy above timber line from 5,000 feet elevation. Stunted balsam fir in a depression in the foreground.

precipitous. The southern trail slope (fig. 2) contains much loose, bare rock and has the appearance of active snow slides. The vegetation below, to the southeast, supports this inference by the injury shown on the stunted balsams. The upper slopes are more stabilized, and when not bare rock or cut by rock and ice slides, are usually clothed with low vegetation, such as shown in figure 3. The cirque is in the lee of the mountain top and is located where snow would be expected to accumulate on account of the prevailing winter winds. This basin has diversified the alpine habitat by making conditions favorable for one of the alpine meadows, while joints or faults are apparently the cause of the formation of the meadows on the southeastern slopes. The rounded dome of the remainder of the mountain-top gives enough stability to the substratum to allow a few alpine meadows to develop.

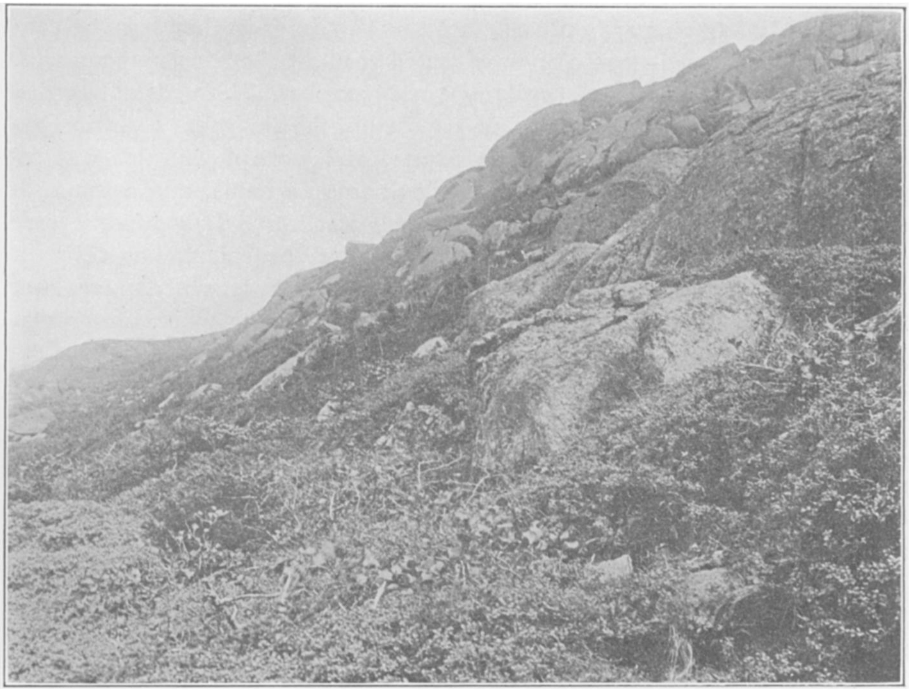


FIG. 3. Upper slopes of Mt. Marcy, showing alpine vegetation with stunted balsam firs in the sheltered spots.

TOPOGRAPHIC AND GEOLOGIC RELATIONS.—The culminating mountain peaks of eastern North America are Mount Mitchell, in the Southern Appalachians, with an elevation of 6,711 feet, Mount Washington, of the White Mountains (6,279 feet), and Mount Marcy or Tahawas (Indian for "Cloud-Splitter") of the Adirondacks, with an altitude of 5,344 feet. The topographic features of the Adirondacks may be summarized as follows:

The Adirondack region is a plateau formed by the uplifting of a peneplain, which now stands at an elevation of about 2,000 feet. Upon this dissected, tilted and much fractured upland arise, in the eastern part, the highest mountains of the Adirondacks. These were probably, in part, monadnocks upon this peneplain before it was elevated. The primary relief of the region is due to the partial development, from this plateau by erosion, of a later lower peneplain, in the main below 2,000 feet, combined with tilting and extensive faulting of mountain blocks, and to cutting and filling by glacial ice and waters. The postglacial changes are relatively slight, including a depression of the region, a re-elevation, the cutting of stream gorges, and the filling of depressions by inwash and organic debris.

The geological history of Mount Marcy, as a part of the Adirondacks, is wonderfully interesting, and certain phases are ecologically significant today. The region is one of the oldest mountain forming areas in the world, and the present mountains are only the latest ones. In fact, they may be considered the truncated stumps or deep seated roots of the former mountains, whose thousands of feet of overlying rock have been elevated and eroded away, so that now the basal roots are exposed at the surface. Even in Precambrian time mountains were here formed and worn down; this was repeated in the Cambrian, and in the Ordovician (Taconic), and again with the Appalachian revolution. Most of these last formed mountains were reduced during the formation of the Cretaceous peneplain, but resistant remnants or monadnocks were preserved (as Marcy), which were later again strongly uplifted (Tertiary) and now form, in the main, the present plateau at 2,000 feet and the higher mountains. The remnants of the Cretaceous peneplain now stand at an elevation of about 2,000 feet, and the Tertiary peneplain, developed below that level. Faulting took place on a large scale, previous to the ice age, and explains many of the southeastward and northwestward facing cliffs. During the ice age there was a depression of the region, overriding by the ice, with scouring and filling by glacial ice and waters, and last of all a slight elevation, with increased erosion.

It may seem strange that down through the ages influences have been at work, many of which, even today, control the life of the plants and animals now living upon the mountain. Thus the ancient igneous rock (anorthosite), has by its resistance retarded erosion and, combined with uplifts, has preserved the elevation, while softer rocks have been removed. This elevation has conditioned the alpine climate, with its many factors. The composition of this rock also, with its varied elements, and its large per cent (10.8) of lime[6] is important. The hardness of this rock is such that the minerals are made available slowly, and the high percentage of lime fails to exert the influence which would be expected. The soils now forming on the mountain from rock fragments are intermingled with the black, acid, organic material and are therefore acid.

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[6] Kemp and Reudemann. "Geology of the Elizabethtown and Port Henry Quadrangles," Bull. N. Y. State Museum, No. 138, p. 32, 1910.

Kemp[7] has called attention to the fact that, through faulting, the higher Adirondacks have a northeast and southwest trend, supplemented by minor faults at right angles to these, which break up the ranges into individual mountains, and thus form saddles or gaps which influence animals. As he expresses it (p. 201), "The little cross-passes almost always have a well-defined bear or deer trail following through." Furthermore, the drainage is affected by such topography and has a direct influence upon aquatic life. We thus see that these physical characteristics, even though of remote origin, exert today a very direct control upon existing organisms. The duration of this mountain has not only maintained Alpine biotic conditions since the ice age, but has perpetuated also a plant and animal population, which are relics of the long ago.

GENERAL ASPECTS OF PLANTS.—The Adirondack region is densely forested, the lower elevations being now characterized by deciduous hardwood forests of beech, birch and maple, with an intermixture of red spruce, balsam fir, hemlock, arbor-vitae, white pine, and few scattered deciduous species. In general, trees of all ages are represented throughout the forest, although under virgin conditions the older trees take up the larger proportion of the space. Young growth is ample in all openings, and even under the shade, owing to the shade enduring character of most of the trees (virtually all but yellow birch). Such woods occupy large areas in the Adirondacks and the Catskills. Their composition and description lie outside the scope of this paper, except where they are replaced by other types of vegetation as one goes up the mountain. The forest floor is often very beautifully covered by myriads of ferns and wild flowers such as *Cornus canadensis, Clintonia borealis, Coptis trifolia, Linnaea Americana, Oxalis Acetosella, Solidago flexicaulis* and others (fig. 4). The typical shrubs are *Viburnum alnifolium, Viburnum cassinoides, Rubus odoratus,* with, of course other species less common.

As one ascends the mountain the hardwoods gradually thin out as to size and frequency of occurrence, being replaced by the red spruce, *Picea rubens,* and balsam fir, *Abies balsamea.* From about 4,250 feet up, which may be considered the upper limit of the red spruce, the balsam fir forms pure stands except for scattering paper birch, *Betula papyrifera.*

In his "Plants of North Elba,"[8] Peck has tabulated the species and families of flowering plants and ferns as follows:

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[7] Kemp, J. F. "The physiography of the Adirondacks," Pop. Sci. Mo., Vol. 68, pp. 195–210, 1906. See also on the geology and topography of the Adirondacks, Miller, W. J., "The geological history of New York," Bull. N. Y. State Museum, No. 168, pp. 1–130, 1914; "The Adirondack Mountains," Bull. No. 193, pp. 1–97, 1917.

[8] Peck, C. H. "Plants of North Elba," pp. 1–266, Bull. N. Y. State Museum, Vol. 6, Number 28, June, 1899.

Families	71
Species	492

Modern segregation of species and the recent discovery of new kinds would probably bring the number somewhat higher, but the fact remains that the Adirondack region, judging by the only reasonably complete flora of it yet published, is characterized by a comparatively small number of species, the bulk of which are very common. Peck's flora included Mt. McIntyre, next to Marcy in altitude, but not Mt. Marcy.

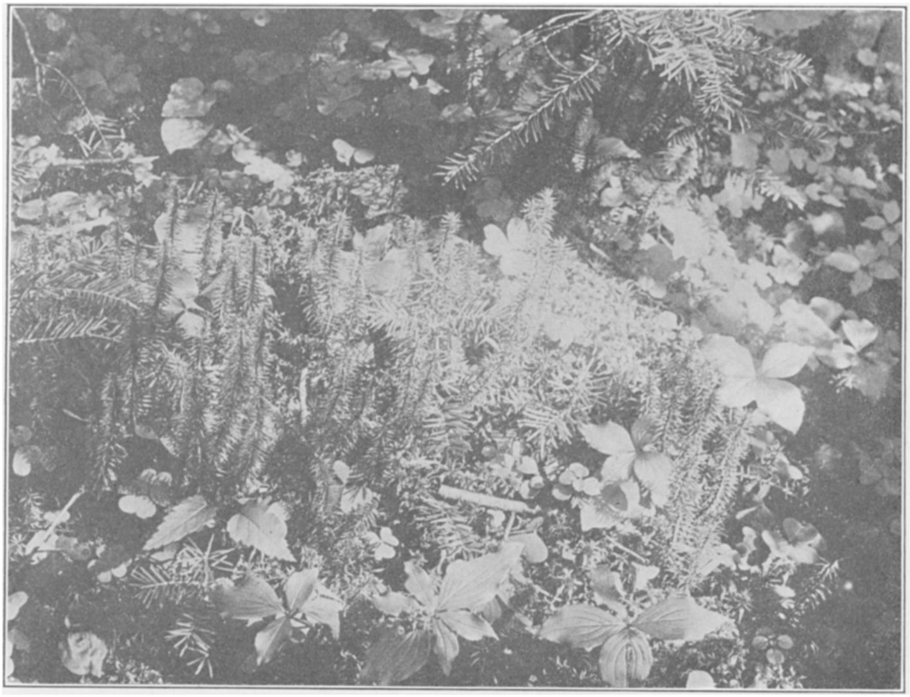

FIG. 4. Vegetation in small opening of pure fir forest at about 4,500 feet elevation, showing *Cornus canadensis, Oxalis Acetosella, Lycopodium,* and fir seedlings.

He included all introduced plants, and we have deducted these from his list, which then shows that 416 species constitute, without recent additions not yet tabulated, the actual wild flora of the mountainous part of the Adirondacks. The great bulk of these plants are of northern affinities, so that the general floristic composition of the region is fairly well indicated by the statement that the Adirondack flora is mostly northern with a limited number of species.

GENERAL ASPECTS OF ANIMALS.—In discussing the animals, in contrast with plants, allowance must be made for the fact that plants remain in evidence during stormy weather while animals tend, in general, not to be so active and attain their maximum activity during bright warm days, and then mainly during the warmest part of these days. The season (August) was also somewhat late for some species. Instrumental work and photographs further limited time for collecting. The relative scarcity of all kinds of animals was among the main features observed. This applied to both the invertebrates and the vertebrates. The scarcity of birds and mammals was conspicuous about our camp in the saddle at 4,355 feet, and these conditions seemed to hold up to the timber line. At camp there was a clearing due to the prolonged use of the site for that purpose. At Lake Tear a collection was made to get representative animals of an *open space,* and for comparison with the open mountain area above the timber line.

Above timber line the poverty of the fauna was very striking, and especially in the small number of animals that can be considered alipne. This is particularly noteworthy in connection with the animals mentioned by Colvin[9] (pp. 363–374) some of which have apparently since disappeared, as also have a number of plants mentioned by Peck as discussed below. The disappearance of the animals is, however, less certain than that of the plants because Colvin's notes were made largely in winter when there would naturally be more alpine animals which had come south. In general the collections suggested that the animals taken were an overflow from the richer lower level. We must look upon the peak of Marcy, with its relatively small area in a sea of forest, as a mere island of open. As a habitat the total area in the Adirondacks above timber line would equal only a small Adirondack lake. This open area in a forest region is somewhat (although inverted) similar to an open swamp or forest glade, and for this reason it is rather natural to expect in such conditions those animals which frequent the forest glades on warm days. The seasonal migration of animals up the mountain, as the season advances, favors just such concentration in the upper open places.

CLIMATE.—Colvin states that, if snow be the criterion, the summit of Mount Marcy enjoys barely two months of summer. Snow often whitens the mountain at the beginning of July, and a temporary covering comes in the first part of September. The climatic winter of the summit commences in the latter part of September or first of October, and ends in June.

No weather station records have been kept on Mt. Marcy and in trying to get some idea of the weather to which the mountain is subjected, the records from the stations nearest to it have been studied. These stations, with their airline distances from the summit of Marcy, and the elevation of them are as follows:

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[9] Colvin, V. "Seventh annual report of the topographical survey of the Adirondack region of New York, to the year 1879." Albany, 1880.

Gabriels	13 miles N.W.	1,729 feet
Lake Placid	7 miles N.	1,864 feet
Keene Valley	4½ miles N.E.	1,012 feet
North Creek	35 miles S.S.W.	1,002 feet
Indian Lake	37 miles S.W.	1,660 feet

Records from stations below 1,000 feet have not been used. A comparison of the records from these five stations, which have been kept over a period of years, shows a good deal of difference in the climate on the north and south-facing slopes of Marcy. Averaging the annual mean temperature shows 42.13° F. for the stations south of the mountain, and 39.54° for those north of it.

The minimum temperature for the stations north of the mountain, averaged over a period of years, is —36°, for the stations south of the mountain —28.4°. The snowfall for stations north of Marcy averages 127 inches (unmelted), while for those to the south it averages 78 inches a year. The maximum temperatures are much more uniform, averaging for the northern stations 92°, and for the southern ones 95°. No continuous records have been kept at the summit of Marcy, but Colvin mentions that a recording thermometer left there by him over the winter of 1875 registered —23°, but it was probably snow covered and "shows the minimum winter temperature of the rock at the summit rather than that of the air."[10]

Due to the precipitous topography, and the purely local nature of early and late frosts, the length of the growing season does not show such well-marked differences as temperature and snowfall appear to do between the north and south sides of the mountain. Taking the region of which Marcy is roughly the center, the growing season has averaged 92 days, compared with about 120 days in the Catskills, and over 200 on Long Island. The longest period has been 142 days; the shortest, 52 days. So far as the weather bureau records show, the latest frost in the spring came on July 20, the earliest on August 18, not, of course, in the same year.

These records give only a very general idea of the climatology of the Marcy region. The amount of variation from day to day, the differences between the south-facing and north-facing slopes, and the apparent waywardness of precipitation in its distribution is baffling if any general statement of the climate of the mountain is attempted. The precipitation is distributed rather uniformly over the year. Eight months have, at different times, shown the highest precipitation of the year. All months have shown the minimum at one time or another. On the whole the precipitation is high and sporadic.

The prevailing winds over a long series of years have been northeast or west, except that at Keene Valley they seem to be about evenly distributed between northwest and south.

[10] Colvin, V. Loc. cit., page 328.

None of the figures cited give any real picture of the climate within the area of this study. The elevation is so much greater, the wind so much stronger, and the exposure near and above timber line relatively so great compared to the weather stations which are in the valleys. On June 5, 1919, near the summit of Marcy we found considerable unmelted snow. The general impression which even a brief period spent there gives, is that during the summer the precipitation is so plentiful that the forest floor just below timber line is wet a considerable part of the time. No one knows definitely how much of the time the mountain is cloud-capped; but certainly the humidity is greater than any records taken 3,500 feet below the summit would suggest. It is nevertheless possible that intervening dry periods may make moisture a limiting factor particularly in exposed situations above timber line.

III. Instrumental Data on the Local Environment

Stations and Instruments.—Certain of the factors that are known to influence the occurrence of plants and animals[11] are capable of measurement and study from the instrumental viewpoint, but the very position of the instruments on Mt. Marcy is naturally dictated by what the vegetation at different elevations shows to be critical points in the vegetative covering of the mountain.

These critical points, at least on the south side, are:

a. Lower limit of fir forest at 4,250 ft.
b. Bog at east end of Lake Tear, at 4,320 ft.
c. 1. Dwarf fir forest just below timber line, at 4,890 ft. in tree crowns.
  2. Same as 1 but on the ground under the forest to show conditions affecting reproduction.
d. Alpine zone above timber line, 4,900 ft. to summit, station at 4,920 ft.

Stations *a* and *b* are about a mile apart and about a thousand feet below the summit. Stations *c* (1 and 2) and *d* are only 75 feet apart and with a difference of but 30 ft. in altitude.

These different types of vegetation, quite unmistakable in their definiteness, and obviously the result of various factors, each occupy large areas on the upper slopes of the mountain, except the bog at Lake Tear which is probably not over 10 acres in extent.

The number and type of instruments used was limited by the practical problem of transportation from the base to the camp near the top of the mountain. For this reason it was impossible to use recording instruments. Evaporation and solar radiation were studied with the Livingston black and white spherical atmometer bulbs. It was not practical to use the rain correcting type. Accordingly, some of the bulbs were mounted on glass tubing which extended into a wide-mouth reservoir through a glass stopper. In this stopper was a second tube of somewhat wider bore which was flush with the bottom of the stopper and extended above the stopper about 1½ inches. This was the filling tube. On it a file mark was made and the distilled water in the reservoir was brought to a level with this mark. A 50 cc. burette was used in refilling the reservoir, and, owing to the small bore of the filling tube, very accurate readings were possible. To prevent water loss through the filling tube a cork stopper with a small groove along one side was used. The other bulbs had only one tube from the bulb to the reservoir and the file mark was made in the neck of the bottle. This type is less satisfactory, because it does not permit such accurate readings.

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[11] Our knowledge of the factors of the environment, and of how they act and how organisms respond, is still very inadequate, but is being increased with gratifying rapidity. Witness Garner and Allard's notable discovery of the control exerted by the relative length of day and night upon the growth and flowering of plants. (Garner, W. W., and Allard, H. A.. "Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants." Jour. Agr. Res.. Vol. 28, pp. 553–605, March, 1920.)

The water loss from the black atmometer was taken as an indication of the solar radiation because it is more influenced by light intensity than the other, and takes into consideration this additional factor, thus giving a more complete record of the complex combination of physical factors which make up a habitat.[12] The solar radiation was determined by subtracting the water loss of the white atmometer from that of the black, expressing the difference in cubic centimeters. Air temperatures were taken with the Weather Bureau type of maximum and minimum thermometers shaded from the sun. The soil temperatures were taken with a soil thermometer.

Station a.—This station was on a steep rocky mountain side facing northeast, at the lower limit of the fir forest where there is still an occasional large spruce representing the upper altitudinal limit of this tree. The reproduction was nearly pure fir (a more complete description of this forest will be found under IV, Plants and Animals). Below this station the spruce increases in proportion, while a short distance higher up it drops out completely. The atmometers were attached to the cut-off tops of fir saplings at a height of 8 to 9 feet above the ground in order to represent the crown conditions of young trees in openings of the forest. The surrounding trees were much higher, ranging up to 45 feet; but owing to the slope of the ground the instruments were fully exposed on the side away from the mountain except for about one hour each day. The topography allowed the sun to strike this slope for about two thirds to three quarters of the period it was above the horizon at this time of year. The thermometers were placed on a tree at 6 feet above the ground under a suitable shelter of boards.

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[12] The importance of solar radiation in controlling transpiration is shown in Briggs and Shantz "Hourly transpiration rate on clear days as determined by cyclic environmental factors." Jour. Agr. Res., Vol. 5, 584–649, 1916, in which they state (p. 647) that "radiation may be looked upon as the primary causative factor in the cyclic changes."

Station b. Lake Tear bog in which this station was located occupies an open area which is nothing more than a widened part of the depression between Mt. Marcy and Mt. Skylight, sheltered on all sides by the surrounding forest and on the northwest and southeast by the mountain slopes as well (See fig. 5). The vegetation consists of bog plants, several alpines, and a few isolated fir trees. The atmometers were placed in the open with their reservoirs buried in the dense mat of sphagnum, the bulbs about 5 inches above the surface of the moss. The thermometers were fastened to an adjacent fir tree at about the same level as that of the atmometer bulbs.

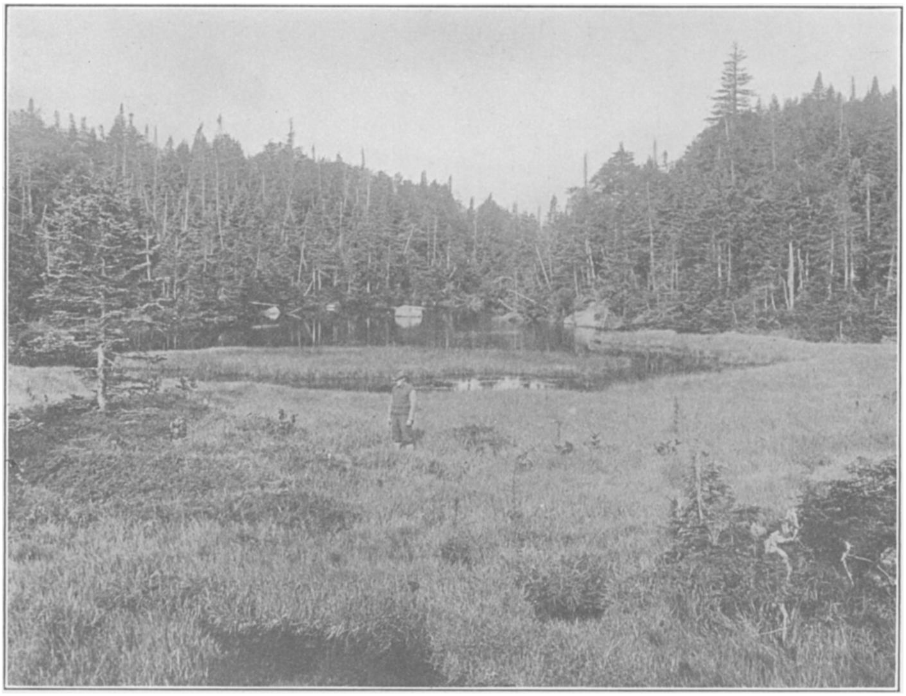

FIG. 5. Lake Tear and the bog, headwaters of the Hudson River, 4,320 feet elevation. Atmometers of station *b* are visible in front of the standing figure.

Stations c 1 and c 2.—These stations were on a shoulder of the mountain in the extreme upper edge of the continuous forest where it reaches timber line. They were in an even stand of fir trees, 7 to 12 feet high, with a maximum breast height diameter of 6 inches, and average of about 3 inches. The tops showed wind damage on the northwest. It seemed best to take records both near the tops of the trees and also under their rather dense crowns. This would give data concerning the conditions under which the

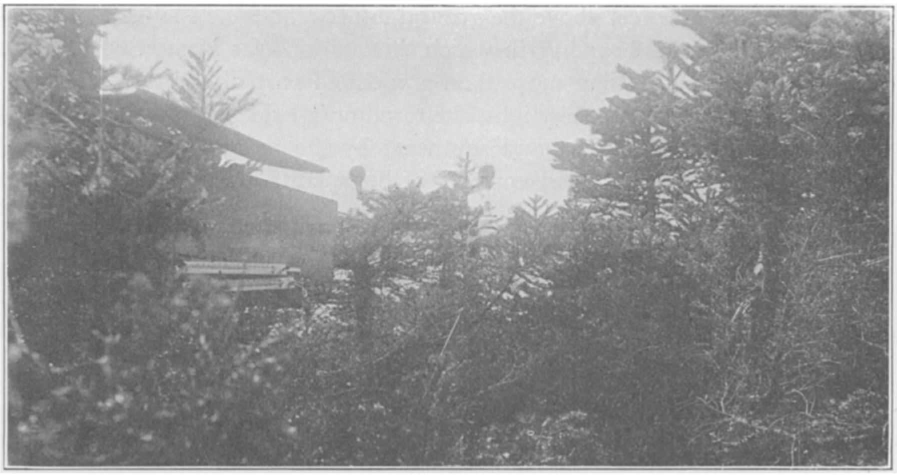

FIG. 6. Station *C*1, showing instruments set in the tops of trees to measure the environment of the forest canopy.

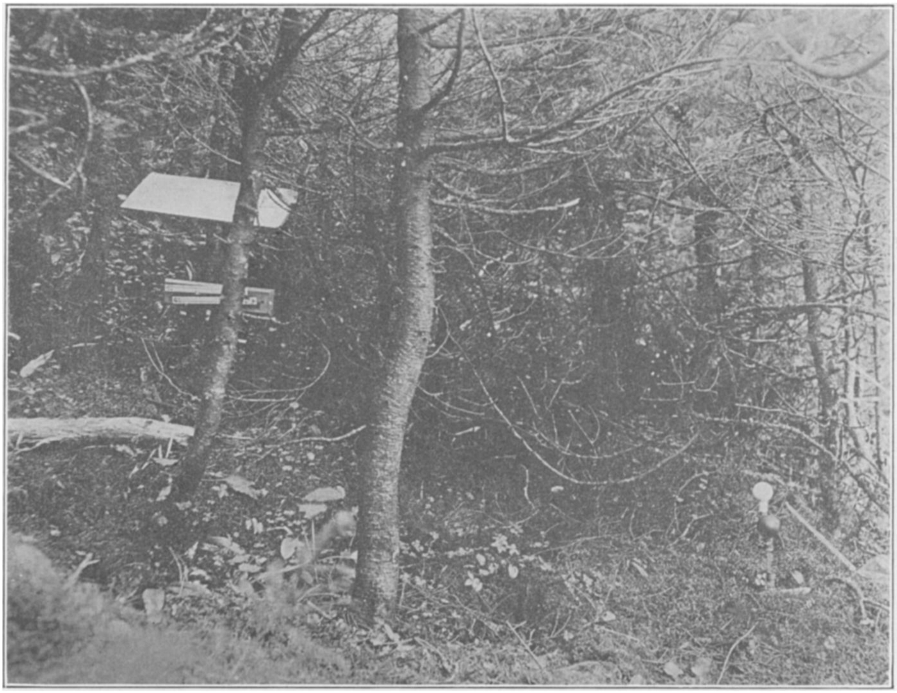

FIG. 7. Station *C*2, showing instruments set under the dense cover of the dwarf fir to measure the environment of the forest floor.

present trees live and an idea of some of the factors influencing natural reproduction. Hence station *c* 1 (fig. 6) and station *c* 2 (fig. 7) were established. In placing the instruments at the former, the tops of trees were removed and the instruments so placed that they were as fully exposed as the tops of the trees had been. The atmometers, especially the white one, could be seen from long distances. The thermometers were located on adjacent trees with similar exposure, care being taken to protect them, however, from the direct rays of the sun. At station *c* 2 the atmometers were placed about 5 inches from the ground, their reservoirs being buried in the heavy covering of moss; the thermometers were attached to trees at about 2 feet above the forest floor. This station was protected from wind, the light was very weak, and the atmosphere was at all times during the study apparently near saturation.

Station d.—This station was located at the lower edge of the alpine vegetation just above the continuous forest. It was on a rock ledge which sloped steeply down to stations *c* 1 and *c* 2, and in one place formed a cliff of about ten feet high. The cliff coincided with timber line. At the station was a layer of peat about four inches thick covered with a dense mat of low shrubs. The atmometers were placed in a north and south line fully exposed. A few yards to the north at the same elevation was a depression in which a few

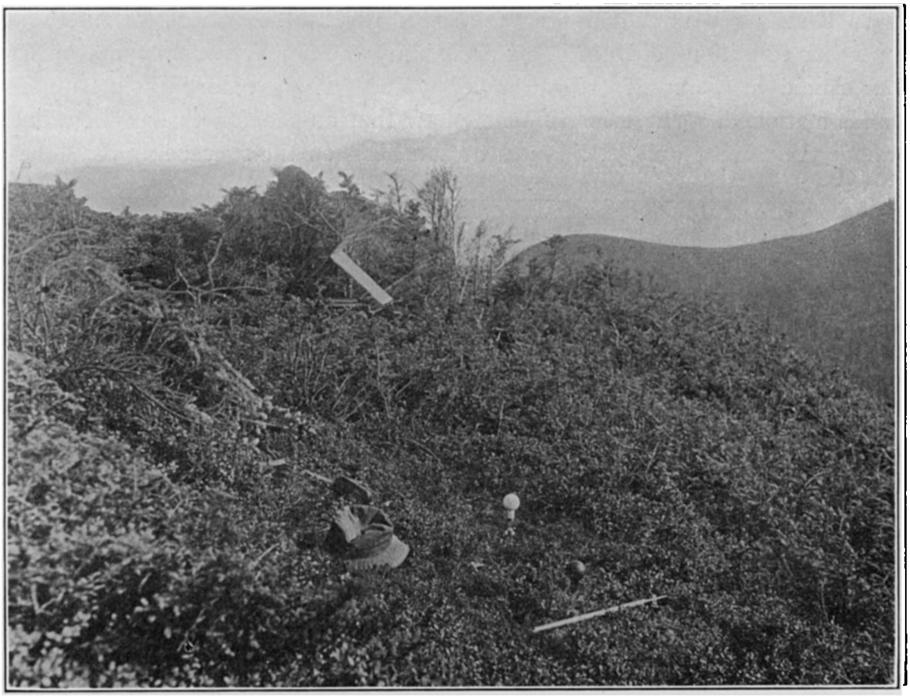

FIG. 8. Station *d* just above timber line, showing atmometers and thermometers.

stunted fir trees reached a height of about 8 feet, their tops extending only a few feet above the general level of the ground. The thermometers, properly protected from the sun, were fastened to one of these trees at about the same elevation as the atmometers (fig. 8).

Evaporation and Solar Radiation.—It was not possible to make readings at such widely distributed stations at 6 a.m. and 6 p.m. as would have been desirable. The readings were taken for the most part between 8 and 9 a.m. and 5 and 6 p.m. They divide the 24 hours roughly into two parts, 10 and 14 hours long respectively, and the graph marked "day" shows the conditions for the shorter period. In the case of the atmometers it was deemed best to add the morning reading to the night reading. This was done because on sunny days the light struck the atmometer a long time before the reading could be made. Very little water evaporated from the bulbs during the night and in fact on rainy nights the reservoir filled so that it was necessary to make the readings from the bottom of the cork stopper instead of from the file mark.

During the first three days of the field study heavy clouds hovered over the mountain tops, and a large part of the time it was raining. The fourth day the sky cleared considerably and the sun appeared. The remaining days were comparatively bright. During the entire period of observation there was a strong wind which was felt especially at the upper stations. The weather conditions did not in all probability differ much from those on Mt. Mansfield in Vermont (elevation 4,075 ft.), where recording instruments were stationed. These instruments show that on the fourth day mentioned above there were only 71 minutes of sunshine, on the succeeding days there were 567, 500, 580, and 60 minutes respectively. The wind movement for these days was 256, 330, 587, 520, and 665 miles respectively. During the night the humidity instrument showed that the air was saturated while during the day the humidity was never lower than 50 percent. These data are shown in figure 9.

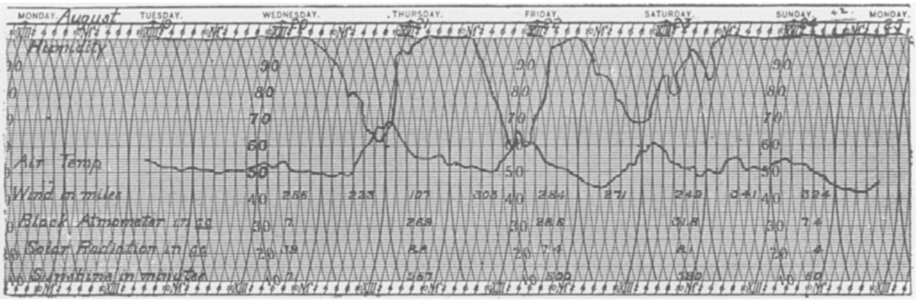

Fig. 9. Weather conditions on Mt. Mansfield, Vermont, August 19 to 25, 1919.

TABLE I. *Evaporation and solar radiation data collected on Mt. Marcy*
Corrected readings of the atmometers and solar radiation expressed in cc.

	Date				
	Aug. 20	Aug. 21	Aug. 22	Aug. 23	Aug. 24
Station *a*:					
Black Atmometer	2.3	16.5	13.5	19.	1.8
White Atmometer	1.5	8.4	6.1	10.3	.7
Solar radiation	.8	8.1	7.4	8.7	1.1
Station *b*:					
Black Atmometer	11.1	20.7	20.6	29.4	5.4
White Atmometer	4.	7.6	9.3	14.6	1.7
Solar radiation	7.1	13.1	11.3	14.8	3.7
Station *c* 1:					
Black Atmometer	9.1	20.	16.4	27.3	4.9
White Atmometer	3.3	7.4	7.	13.3	2.
Solar radiation	5.8	12.6	9.4	14.	2.9
Station *c* 2:					
Black Atmometer	0.	3.7	2.1	5.8	3.5
White Atmometer	.5	3.2	1.5	5.4	3.
Solar radiation	0.	.5	.6	.4	.5
Station *d*:					
Black Atmometer	12.9	24.	20.7	36.2	6.6
White Atmometer	5.6	9.7	12.	20.	2.6
Solar radiation	7.3	14.3	8.7	16.2	4.

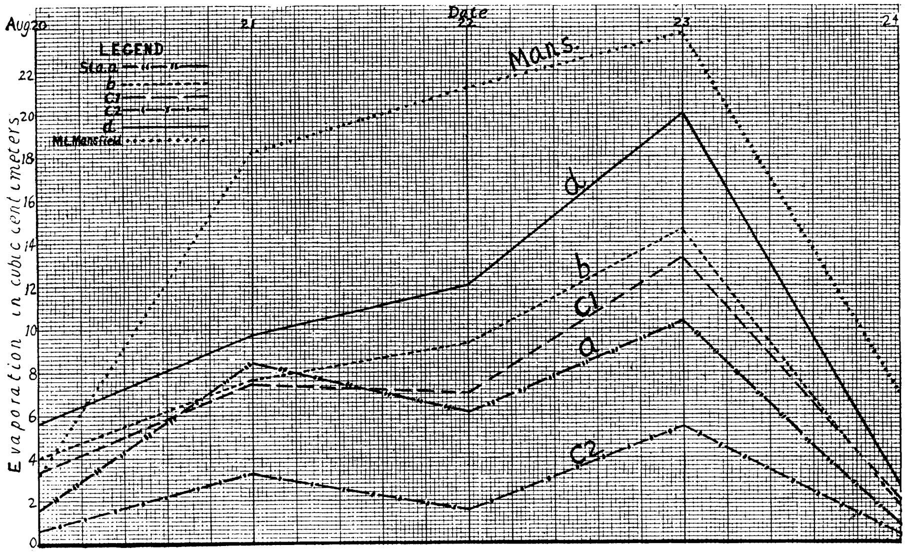

FIG. 10. Evaporation from white spherical atmometers at each station on Mt. Marcy from August 20 to 24, 1919. Evaporation at the summit of Mt. Mansfield, Vermont, is included for comparison.

The corrected readings of the two types of atmometers are given in table 1, and are shown graphically in figures 10, 11 and 12. Figure 10 shows the evaporation from the white atmometers. The highest evaporation occurs above timber line at station *d*, and, except for station *c* 2 which was under the dense fir, and station *c* 1 which will be discussed below, the rate of evaporation shows a tendency to increase with elevation (see also fig. 11).

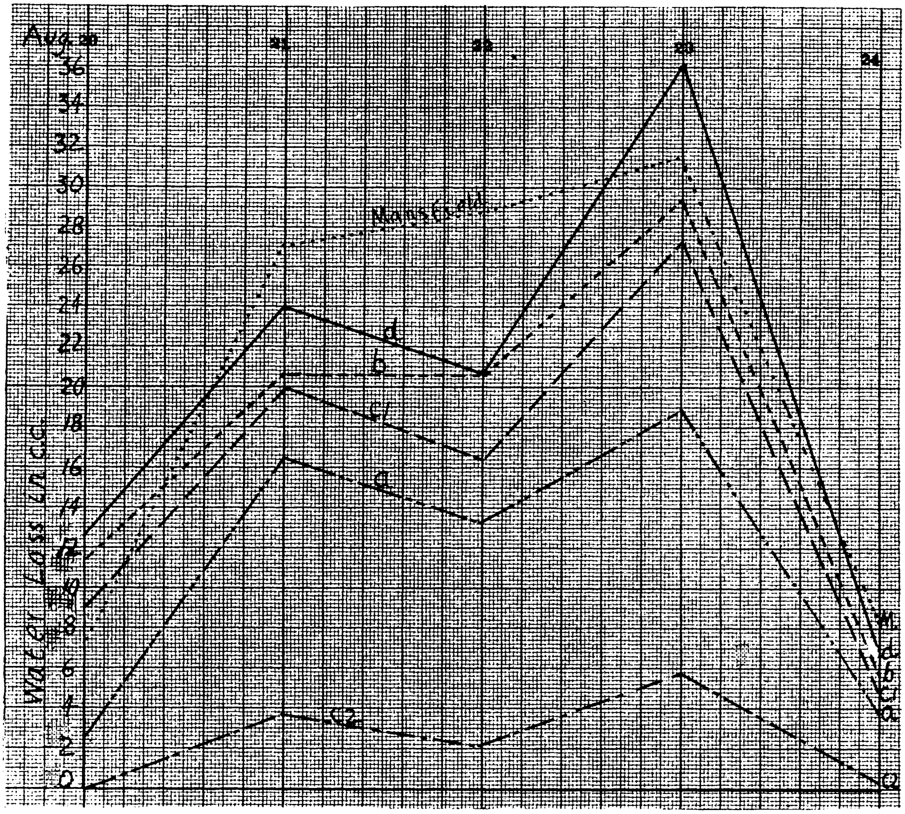

FIG. 11. Water loss from black spherical atmometers at each station on Mt. Marcy, and at the summit of Mt. Mansfield.

The rate in the bog (station *b*) is higher than the rate on the mountain side just below timber line (station *c* 1) in spite of the greater exposure to sun and wind movement at the latter point. This cannot be due to greater cloudiness at station *c* 1, because station *d*, only 75 feet away, showed an even higher evaporation than the bog. It can hardly be due to interception of the wind by the surrounding tree tops because the atmometers were placed above the shelter of these. The question presents itself as to whether or not the stream of moisture transpired by the trees and drawn upward from the forest floor, which at this time was very wet, can be the cause of the lower evaporating rate just below timber line as compared with that just above and in the bog. The moisture transpired by the trees is in all probability greater than that transpired by the much thinner layer of comparatively xerophytic bog plants; that coming through the forest from below, is also probably greater than that which comes from the sphagnum of the bog. It is therefore not unlikely that the volume of moisture coming up from the forest is enough greater than that rising from the bog to produce the difference in evaporation shown by the instruments.

Figure 11 represents graphically the water loss from the black atmometers. Here again the highest rate occurs just above timber line. The stations arrange themselves in the same order as for the white atmometers except that the rate at the lowest station (*a*) is lower than that at the bog (*b*) throughout.

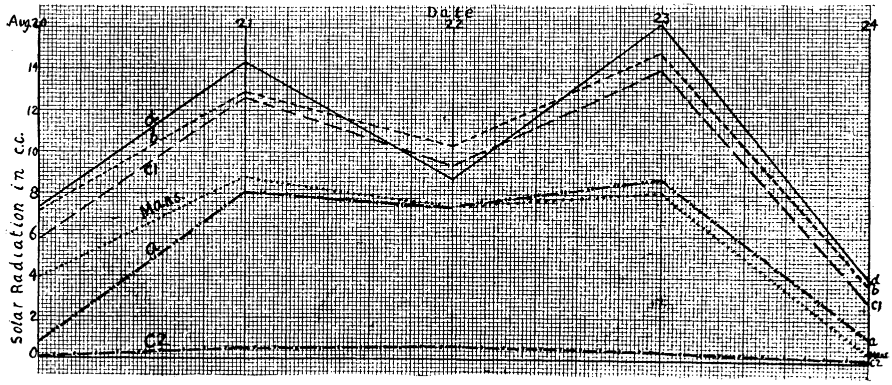

FIG. 12. Solar radiation expressed in cubic centimeters, at each station on Mt. Marcy and at the summit of Mt. Mansfield.

A comparison of the graph representing the rate of evaporation from the top of Mt. Mansfield shows a marked similarity with Mt. Marcy except on August twenty-second when it does not have the dip shown on Marcy.

Figure 12 shows graphically the amount of solar radiation as expressed by the difference between the water loss from the white and black atmometers given in number of cubic centimeters. Solar radiation above timber line was the greatest. If this be taken as 100 percent then the stations arrange themselves as follows: Station *d*, 100 percent; Station *b*, 99 percent; station *c* 1, 89 percent; station on Mt. Mansfield, 56 percent; station *a*, 51 percent, station *c* 2, 4 percent.

It was observed that at times the sun rays pierced the crowns of the fir trees above *c* 2, and struck the bulbs for a few minutes. This probably accounts for the small amount of solar radiation there. In a similar station on Mt. Mansfield during this same period no solar radiation was recorded. Although the fir seedlings have excellent moisture conditions for establishment, as indicated by the low evaporation at station *c* 2, the sunlight which penetrates the dense canopy is insufficient for their development; only when the cover is opened by the death of an old tree can the young trees come up.

The three chief factors which enter into the consideration of the variations recorded above are elevation, clouds and exposure. Station *c* 2, as has been said, was never long subjected to the direct rays of the sun. Station *a* was shaded during part of the day by Mt. Skylight and the vegetation on the mountain side. Local clouds were abundant. At times *d* and *c* 1 were in the clouds while *b* was in the bright sunlight. At other times a heavy mist would cover the atmometers at *b* while the upper stations were in the sunshine.

It is interesting to note that while the water-losses from both the white and black atmometers on Mt. Mansfield at an elevation of 4,075 feet were larger than from any station on Mt. Marcy, the solar radiation was only 56 percent of that above timber line on Marcy.

TEMPERATURE.—The temperature readings are given in table 2, and shown graphically in figures 13 and 14. The variations from day to day were not great at any of the stations, the maxima varying a little more than the minima. The differences in maximum and in minimum temperature between the stations were small.

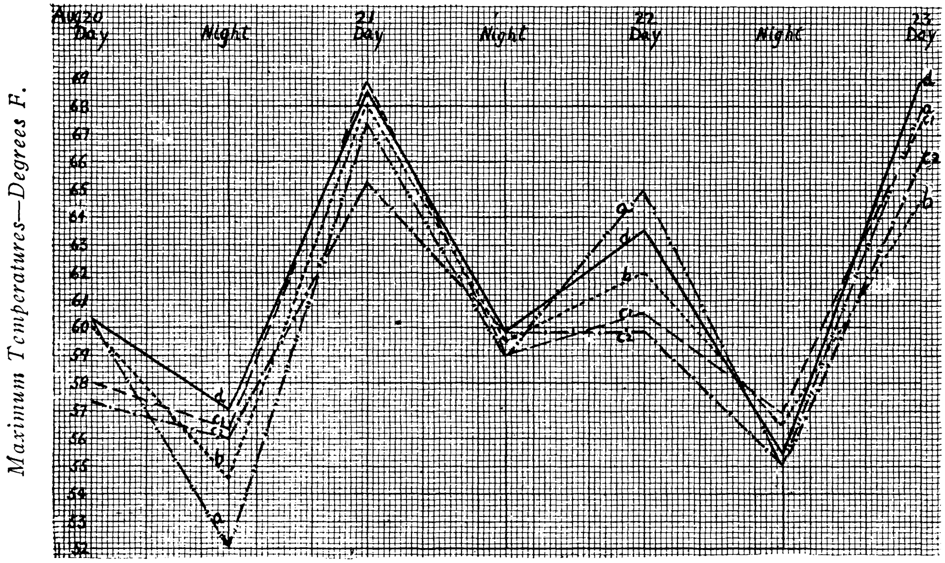

FIG. 13. Maximum temperatures at each station on Mt. Marcy.

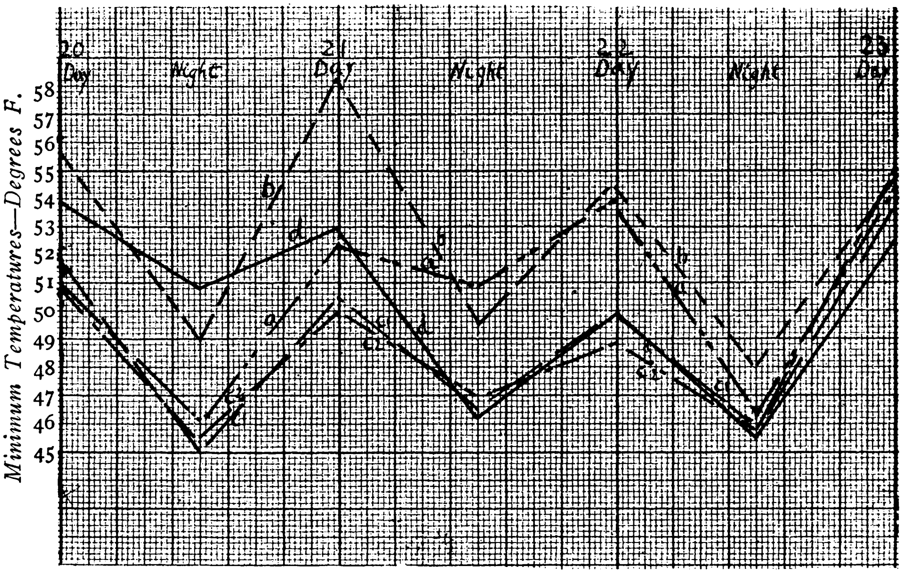

FIG. 14. Minimum temperatures at each station on Mt. Marcy.

TABLE 2. *Temperature readings on Mt. Marcy, August, 1919*

Station	20	21		22		23		24
	Day	Night	Day	Night	Day	Night	Day	Day*
a. Max.	60.3	52.	67.4	59.	65.	55.	67.8	60.9
Min.	51.	46.	52.3	50.9	54.	46.2	54.5	50.
Ave.	55.6	49.	59.9	55.	59.5	50.6	61.7	55.5
b. Max.	60.	54.5	68.	59.5	62.	56.5	64.5	59.7
Min.	55.5	49.	58.2	49.5	54.5	48.	54.8	55.8
Ave.	57.8	51.8	63.1	54.5	58.3	52.3	59.7	57.8
c – 1. Max.	58.	56.3	68.8	59.	60.5	56.9	67.6	58.9
Min.	51.8	45.	50.4	46.5	49.9	45.4	53.5	49.8
Ave.	54.9	50.7	59.6	52.8	55.2	51.1	60.6	54.4
c – 2. Max.	57.3	56.	65.3	59.8	59.9	55.	66.1	58.8
Min.	51.	45.4	50.	46.9	48.8	45.7	51.	49.5
Ave.	54.2	50.7	57.7	53.4	54.4	50.1	58.6	54.2
d. Max.	60.3	57.	68.5	59.8	63.5	55.3	68.9	58.7
Min.	53.8	50.8	53.	46.3	49.8	45.5	52.4	46.9
Ave.	57.	53.9	60.8	53.	56.7	50.4	60.7	52.8

* No night readings for August 23–24.

Bonnier[13] states (p. 336) that the modifications of structure in alpine plants are related to the diurnal range of temperature, which is very low at night and relatively high in the sun during the daytime. Although our thermometers were sheltered from the direct rays of the sun (which gives a smaller range), our results agree in the main with the set of conditions found by Bonnier. The average range of temperature (difference between maximum and minimum) increased with altitude except that the station just below timber line (*c* 1) had a little greater range than just above timber line (*d*). The average ranges, in order of magnitude, are as follows:

Station *c* 1	11.7	degrees F.
Station *c* 2	11.3	" "
Station *d*	10.5	" "
Station *b*	7.4	" "
Station *a*	7.1	" "

Sampson[14] has shown, as a result of studies in the plant zones of the Wasatch Mountains in Utah, that the summation of effective temperatures as proposed by Merriam[15] gives results similar to temperature summations on the physiological basis as devised by Lehenbauer.[16] These summations "have shown much promise in correlating air temperature with physiological plant activities." Summations of our temperature data according to Merriam's method (totals of the mean daily temperature, less 40 degrees) show that the heat available for growth diminishes with increasing altitude, except for the bog at Lake Tear which had the highest effective temperature, due undoubtedly to its longer exposure to the sun as compared with station *a*. Taking the effective temperatures at station *a* as 100 percent, the other stations were as follows:

Station *a*	100	per cent.
Station *b*	105	" "
Station *c* 1	95	" "
Station *c* 2	89	" "
Station *d*	76	" "

It is significant that the greatest change in amount of effective temperatures should occur between the points just below and just above the timber line, in spite of the short distance (hardly 75 feet) between these two points, and that this change should correspond with the abrupt contact between the two life zones. Does not this suggest that the amount of effective temperature may be the leading factor which causes the sharp line of demarkation at timber line?

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[13] Bonnier, Gaston, "Le Monde vegetal" E. Flammarion, Paris, 1914.

[14] Sampson, A. W. "Climate and plant growth in certain vegetative associations," U. S. Dept. Agr. Bul. 700: 1–72. 1918.

[15] Merriam, C. Hart. "Laws of temperature control of the geographic distribution of terrestrial animals and plants," Nat. Geog. Mag., Vol. 6, pp. 229–238, 1894.

[16] Lehenbauer, P. A. "Growth of maize seedlings in relation to temperature," Physiological Researches, Vol. 1, No. 5, pp. 247–288, 1914.

SOIL TEMPERATURE.—The soil at all stations was essentially a bog soil. Analysis shows that its water content varied from 76 percent to 85 percent, of its original weight. As is well known, soils of this nature do not fluctuate much in temperature on account of the great mass of water to be warmed. The readings obtained were:

TABLE 3. *Soil temperature.*

Depth	Stations			
	a	*b*	*c1* and *c2*	*d*
1½ in.	54	58.5	53	55
3 "	52.5	53.5	49.3	50
8 "	—	—	—	47.5
12 "	50	49.5	46.3	—

Temperature in adjacent sandy soils at a depth of one inch were about 20 degrees warmer during the afternoon on sunny days and fluctuated as much as 13 degrees during 24 hours. On one day the maximum soil temperature at this depth was 76 degrees, the minimum, 63°.

SOILS.—Samples of the surface soil were taken in each of the important types of vegetation represented by the stations described above. Since the feeding roots of most plants are close to the surface these samples are fairly representative, although final conclusions would require a larger number, including some of the deeper layers. The mineral soil over most of Mount

TABLE 4. *Soil samples from Mt. Marcy.*

Station	Water, percent	Dry matter, percent	Dry matter contains organic and volatile sub., percent	Ash, percent	Organic and volatile contain nitrogen, percent	Relative lime absorption coefficient	Depth of sample
b	84.79	15.21	12.24	2.97	.312	1	8 in.
b	82.64	17.36	13.40	3.96	.304	1.2	1 ft.
d	76.07	23.93	21.93	2.00	.500	2.2	8 in.
c	80.31	19.69	18.89	.80	.455	2.3	1 ft.
a	81.36	18.64	17.62	1.02	.388	2.1	1 ft.
d	50.75	49.25	17.78	31.46	.389	1.5	8 in.

	100 parts dry matter contain			
	Organic and volatile	Ash	Nitrogen in organic matter	Depth of sample
b	80.47	19.53	2.05	8 in.
b	77.20	22.80	1.75	1 ft.
d	91.63	8.37	2.09	8 in.
c	95.05	4.05	2.31	1 ft.
a	94.53	5.47	2.08	1 ft.
d	36.10	63.90	.79	8 in.

Quality of organic and volatile matter as regards nitrogen is nearly similar. All samples show a large lime absorption coefficient, indicating high acidity.

Marcy is derived from a coarsely crystalline, greenish anorthosite containing approximately ten percent of lime. This rock, even when pounded to powder, gave a hardly perceptible effervesence with hydrochloric acid, but when heated it effervesced strongly.

The analyses of the samples are given in table 4. None except sample 6 contained appreciable quantities of the mineral soil. It is interesting that the mineral soil, even though derived from rock with a marked percentage of lime is nevertheless acid. The analyses indicate that the major differences in the vegetation at the instrumental stations are probably not due to differences in the soil. There are however, examples of plant responses to soil composition as in the case of *Arenaria groenlandica* and *Scirpus caespitosus* which grow on the particles of the rock that do not yet contain sufficient organic matter to become strongly acid. Such a case is noted below under the description of the vegetation of the alpine zone.

The above data probably do not cover a critical period in the conditions of the habitats which were under consideration. At no time were the plants subjected to extreme conditions in light intensity, air or soil temperatures, humidity or soil moisture. Only data collected at such critical periods, that is when one or more of the environmental factors was reduced to its minimum for that habitat, could be used to determine its effect upon plant distribution. That periods exist when conditions are less favorable than they were during our stay was plainly recorded by the vegetation. Although not covering a critical period, the instrumental data indicate certain important differences in the habitats studied, and the authors believe that the collection of this kind of data is valuable in pointing the way to the solution of many problems in plant distribution.

(*To be continued*)

Part II will contain Section IV, the detailed descriptions of the plants and animals on the various habitats mentioned above, and their ecological significance.

Part III will contain the remainder of the paper, including a map and discussion of tree distribution in relation to wind, data on the rate of tree growth above and below timber line, and an analysis of the vegetation in accordance with Raunkiaer's growth forms.